

# DIANA, a program for Feynman Diagram Evaluation

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## Abstract

A C-program DIANA (DIagram ANALyser) for the automatic Feynman diagram evaluation is presented. It consists of two parts: the analyzer of diagrams and the interpreter of a special text manipulating language. This language is used to create a source code for analytical or numerical evaluations and to keep the control of the process in general.

Recent high precision experiments require, on the side of the theory, high-precision calculations resulting in the evaluation of higher loop diagrams in the Standard Model (SM). For specific processes thousands of multiloop Feynman diagrams do contribute. For example, in the calculation of the anomalous magnetic moment of the muon  $\frac{1}{2}(g - 2)_\mu$  there are 1832 diagrams in two loops. Of course, the contribution of most of these diagrams is very small. But sometimes it is not so easy to distinguish between important and unimportant diagrams. On the other hand, we often need to take into account all diagrams, to verify gauge independence, or cancellation of divergences. It turns out impossible to perform these calculations by hand. This makes the request for automation a high-priority task.

Several different packages have been developed with different areas of applicability (for a review see [1]). For example, there are several well-known Mathematica packages: FeynArts / FeynCalc [2] are convenient for various aspects of the calculation of radiative corrections in the SM, TARCER [3] - a program for the reduction of two-loop propagator integrals. There are also several FORM packages for evaluating multiloop diagrams, like MINCER [4], and a package [5] for the calculation of 3-loop bubble integrals with one non-zero mass. Other packages for automation are GRACE [6] and CompHEP [7], which partially perform full calculations, from the process definition to the cross-section values.

A somewhat different approach is pursued by XLOOPS [8]. A graphical user interface makes XLOOPS an 'easy-to-handle' program package. Recent development of XLOOPS is aimed at the evaluation of all diagrams occurring in given processes, but at present it is mainly aimed to the evaluation of single diagrams.

To deal with thousands of diagrams, it is necessary to use special techniques like databases and special controlling programs. In [9] for evaluating more than 11000 diagrams the special database-like program MINOS was developed. It calls the relevant FORM programs, waits until they finished, picks up their results and repeats the process without any human interference.

It seems impossible to develop an universal package, which will be efficient for all tasks. Various ways will be of different efficiency, have different domains of applicability, and

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should eventually allow for completely independent checks of the final results. This point of view motivated us to seek our own way of automatic evaluation of Feynman diagrams.

To understand the idea, let us look at the new package GEFICOM [10].

This package was developed for computation of higher order processes involving a large number of diagrams. It is based on cooperative use of several software tools such as Mathematica, FORM, FORTRAN, etc.

The obvious advantage of such an approach is that all partial tasks can be solved by means of the most convenient software tool.

But many kinds of the system-depending software lead to problems:

1) Problems with portability: such a system requires use of many operational system resources and strongly depends on them. E.g, the most popular family OS MS Windows has not enough abilities. 2) Problems with the installation process for non-specialists. 3) Usually, such a system is elaborated “ad hoc”, and it is very difficult to change its general structure.

Our aim is to create some universal software tool for piloting the process of generating the source code in multi-loop order for analytical or numerical evaluations and to keep the control of the process in general. Based on this instrument, we can attempt to build a complete package performing the computation of any given process in the framework of any concrete model.

It is worth noting that such approach is widely used nowadays. For example, the well-known package FormCalc [11] uses Mathematica as a front-end for FORM. Combining the advantages of Mathematica and FORM, this package is well suited for the big one-loop level problems.

But, Mathematica is too big and slow to guarantee controlling facility for the calculation of a huge process. From this point of view, it is overloaded by many unnecessary built-in functions; it was elaborated for solving a bit other problems. It is not so efficient when it is used as a shell language.

There are many software tools elaborated specially for these tasks. Usually, the “make” utility is used combining with some shell language, like the PERL interpreter. Here, again, problems specific for heterogeneous systems appear. And, many languages in use make difficulties for non-specialists to deal with such a system.

We need the “scripting” language suitable for both controlling the various software and generating the source code for this software. All existing languages either are not powerful enough or too complicated for non-specialists.

For the project called DIANA (DIagram ANALyser) [12] for the evaluation of Feynman diagrams we have elaborated a special text manipulating language (TM).

The TM language is a TeX-like language for creating source code, organizing the interactive dialog and so on. It is very simple, but, nevertheless, it is very configurable and extensible.

Similar to the TeX language, all lines without special escape - characters (“\”) are simply typed to the output file. So, to type “Hello, world!” to the terminal we may write down the following program:

```
Hello, world!
```

Each word, the first character of which is the escape character, will be considered as a

command. There are many built-in commands returning the information about diagrams. For example, if the user writes in the input file

```
\mass(2),
```

in the output file the value of the particle mass on line number 2 appears.

For generating Feynman diagrams we use QGRAF [13]. DIANA reads QGRAF output. For each diagram it performs the TM-program, producing input for further evaluation of the diagram. Thus the program:

Reads QGRAF output and for each diagram it: 1) Determines the topology, looking for it in the table of all known topologies and distributes momenta. If we do not yet know all needed topologies, we may use the program to determine missing topologies that occur in the process. 2) Creates an internal representation of the diagram in terms of vertices and propagators. 3) Executes the TM-program to insert explicit expressions for the vertices, propagators etc. The TM-program produces input text for FORM ( or some other language), and executes the latter (optionally).

Using the TM language, advanced users can develop further extensions, e.g. including FORTRAN, to create a postscript file for the picture of the current diagram, etc.

The program operates as follows: first of all, it reads its configuration file, which may be produced manually or by DIANA as well. This file contains: 1) The information about various settings (file names, numbers of external particles, definition of key words, etc.) 2) Momenta distribution for each topology. 3) Description of the model (i.e., all particles, propagators and vertices). 4) TM-program.

The TM-program is part of the configuration file. It starts with the directive

```
\begin translate
```

Then the program starts to read QGRAF output. For each diagram it determines the topology, assigns indices and creates the textual representation of the diagram corresponding to the Feynman integrand. All defined data (masses of particles, momenta on each lines, etc.) are stored in internal tables, and may be called by TM-program operators. At this point DIANA performs the TM-program. After that it starts to work with the next diagram.

When all diagrams are processed, the program may perform the TM-program a last time (optionally). This may be used to do some final operations like summing up the results.

Use of the TM language makes DIANA very flexible. It is easy to work out various algorithms of diagram evaluation by specifying settings in the configuration file or even by a TM program.

Let us suppose that we use FORM as formulae manipulating language.

The user types his FORM program and has the possibility to insert in the same line TM-operators as well. For example, the typical part of a TM program looks like follows:

```
\program
\setout(d\currentdiagramnumber().frm)
#define dia "\currentdiagramnumber()"
#define TYPE "\type()"
#define COLOR "\color()"
```

```

#define LINES "\numberofinternallines()"
\masses()
#include def.h
l R=\integrand();
#call feynmanrules{}
#call projection{}
#call reducing{'TYPE'}
#call table{'TYPE'}
#call colorfactor{'COLOR'}
.sort
g dia'dia' = R;
drop R;
.store
save dia'dia'.sto;
.end
\setout(null)
\system(\(form -l )d\currentdiagramnumber().frm)

```

This TM-program will generate the FORM input for each diagram. For example, the corresponding part of the FORM program generated for diagram number 15 will be placed into the file “d15.frm” and looks like follows (for the detailed explanation of this example see [12], Appendix A):

```

#define dia "15"
#define TYPE "4"
#define COLOR "3"
#define LINES "4"
#define m1 "mmH"
#define m2 "mmW"
#define m3 "mmW"
#define m4 "mmH"
#include def.h
l R=
    1*V(1,mu1,mu,2)*(-i_)*em^2/2/s*V(2,0)*(-i_)*1/4*em^2/s^2*mmH/mmW*
    V(3,mu2,+q4-(+q3),1)*(-i_)*em/2/s*SS(1,0)*i_*VV(2,mu1,mu2,+q2,2)*i_*
    SS(3,2)*i_*SS(4,0)*i_;
#call feynmanrules{}
#call projection{}
#call reducing{'TYPE'}
#call table{'TYPE'}
#call colorfactor{'COLOR'}
.sort
drop R;
g dia'dia' = R;
.store
save dia'dia'.sto;
.end

```

Then this program will be executed by FORM by means of the operator

`\system(\(form -l )d\currentdiagramnumber().frm)`

In this case the operator performs the command

`form -l d15.frm`

There is a possibility to use DIANA to perform the TM-program only, without reading QGRAF output. If one specifies in the configuration file `only interpret` then DIANA will not try to read QGRAF output, but immediately enters the TM - program.

DIANA contains a powerful preprocessor. The user can create macros to hide complicated constructions. Similar as LaTeX provides the possibility for non-specialists to typeset high-quality texts using the TeX language, these macros permit DIANA to work at very high level. The user can specify the model and the process, and DIANA will generate all necessary files [12].

At present DIANA is available only upon request from the authors.

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